Luigi Caretti
Lucio Buratto
Editors

Glaucoma Surgery

Treatment and Techniques

Springer

Glaucoma Surgery

Luigi Caretti • Lucio Buratto
Editors

Glaucoma Surgery

Treatment and Techniques

Springer

Editors
Luigi Caretti
Santa Maria della Misericordia Hospital
Rovigo
Italy

Lucio Buratto
Centro Ambrosiano Oftalmico
Milan
Italy

ISBN 978-3-319-64854-5 ISBN 978-3-319-64855-2 (eBook)
http://doi.org/10.1007/978-3-319-64855-2

Library of Congress Control Number: 2017960213

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

1 Anatomy 1
Luigi Caretti and Lucio Buratto

2 Anesthesia 5
Luigi Caretti and Lucio Buratto

3 Penetrating Surgery and Its Surgical Variants 7
Luigi Caretti and Lucio Buratto

4 Non-penetrating Glaucoma Surgery (NPGS): Viscocanalostomy, Deep Sclerectomy and Canaloplasty 23
Luigi Caretti and Lucio Buratto

5 Glaucoma Drainage Implants 41
Luigi Caretti and Lucio Buratto

6 Surgical Iridectomy 55
Luigi Caretti and Lucio Buratto

7 Pediatric Glaucoma 61
Luigi Caretti and Lucio Buratto

8 Mini-Invasive Glaucoma Surgery (MIGS) 69
Luigi Caretti, Lucio Buratto, and Monika Baltaziak

9 Trabectome (Trabeculectomy Ab Interno) 75
Luigi Caretti and Lucio Buratto

10 Schlemm Canal Device 79
Luigi Caretti and Lucio Buratto

11 Supra-Choroidal Devices 83
Luigi Caretti and Lucio Buratto

12 Ab Internal Stent 91
Luigi Caretti and Lucio Buratto

13 Medical Antiglaucomatous Therapy 97
Silvia Babighian

14 Laser Antiglaucomatous Treatments 99
Silvia Babighian

15 The Choice of Glaucoma Treatment 107
Silvia Babighian

16 Glaucoma Devices 109
Amrit Rai and Iqbal Ike K. Ahmed

17 Deep Sclerectomy 121
Norbert Koerber

18 Canaloplasty Surgical Technique 125
Gabor Scharioth

Index 131

Anatomy

1

Luigi Caretti and Lucio Buratto

In glaucoma surgery, comprehensive knowledge and understanding of the sclero-corneal limbus and the anatomy of the irido-corneal angle (Figs. 1.1, 1.2, 1.3, 1.4, 1.5, and 1.6) are absolutely essential.

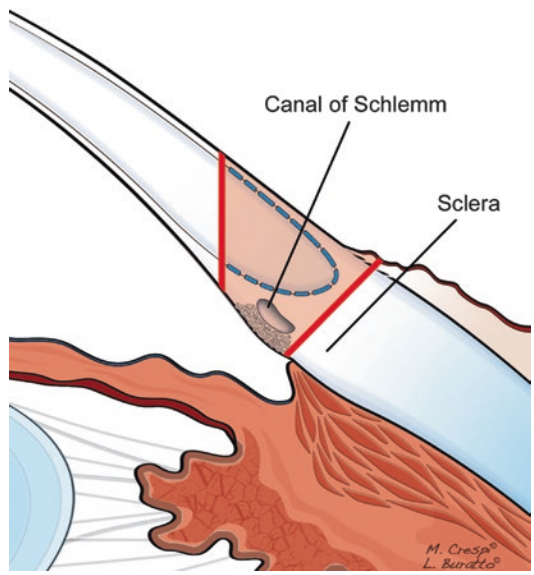

Fig. 1.1 Anatomy of the limbus (in section).
– the *red lines* define the block of tissue known as the limbus;
– the *broken blue line* indicates the transition zone between the cornea and the sclera.
The limbus is approximately 1 mm wide, and it is larger on the vertical meridian where cornea and conjunctiva epithelium merge on the boundary with the Bowman membrane. Posterior to this border, the clear and bluish fibers of the cornea merge with the white and opaque fibers of the sclera. In this point, they separate to get the insertion of the corneal fibers: this results in a clearly visible bluish transition band.
The recognition of these important anatomical landmarks is essential for correct surgical access to the angular structures. Infact the termination point of these corneal fibers lies above the scleral spur and the root of the iris; consequently, this is an important surgical landmarks for the structures of the iris-corneal angle

L. Caretti (✉)
Santa Maria della Misericordia Hospital, Rovigo, Italy
e-mail: oculistica.ro@azisanrovigo.it

L. Buratto
Centro Ambrosiano Oftalmico, Milan, Italy
e-mail: iol.lasik@buratto.com

L. Caretti, L. Buratto (eds.), *Glaucoma Surgery*, http://doi.org/10.1007/978-3-319-64855-2_1

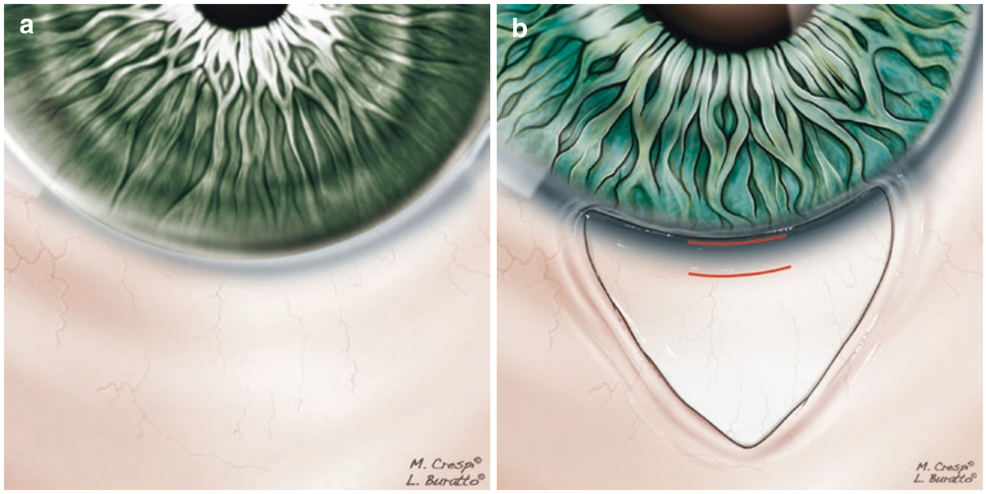

Fig. 1.2 Anatomy of the limbus (view from above).
(**a**) Limbus prior to the conjunctival dissection
(**b**) Limbus following the conjunctival dissection. In the drawing, it is outlined by *red* markings.
The surgical limbus is the *blue-gray* area lying between the sclera and the clear cornea (outlined by *red* markings); it can be identified following the removal of the conjunctiva and the Tenon's capsule (**b**). Its posterior margin normally overlaps the anterior portion of the sclero-corneal trabecular meshwork. Schematically we can identify the following structures, from anterior to posterior: the anterior margin of the limbus, consisting of the Schwalbe line, the posterior boundary consisting of the scleral spur, and finally the trabecular meshwork that lies between these two structures. The conjunctiva and the Tenon's capsule are inserted into the cornea at the Bowman membrane, and cover the limbus. In most anti-glaucomatous surgeries (particularly if they are penetrating), the conjunctiva and the Tenon's capsule must be respected and handled with care: the integrity of these structures makes an important contribution to the surgical outcome. The Tenon's capsule is firmly adhered to both the conjunctiva above and the episclera below, along a line that extends for approximately 1 mm posteriorly to the sclero-corneal junction. Because of this anatomical relationship during the preparation of a fornix based flap it is possible to dissect the conjunctiva and the capsule together, as though the two structures formed a single layer, starting the incision in correspondence with the external limit of the Bowman membrane. This type of dissection is little traumatic and permits easy and accurate restoration of the original anatomical relationships. A thin and highly-vascularized layer of connective tissue—called the episclera—is located below the Tenon's capsule. Consequently, from the outside to the inside, there is the alternation of highly-vascularized layers, such as the conjunctiva and the episclera, and completely avascular layers, such as the Tenon's capsule and the sclera

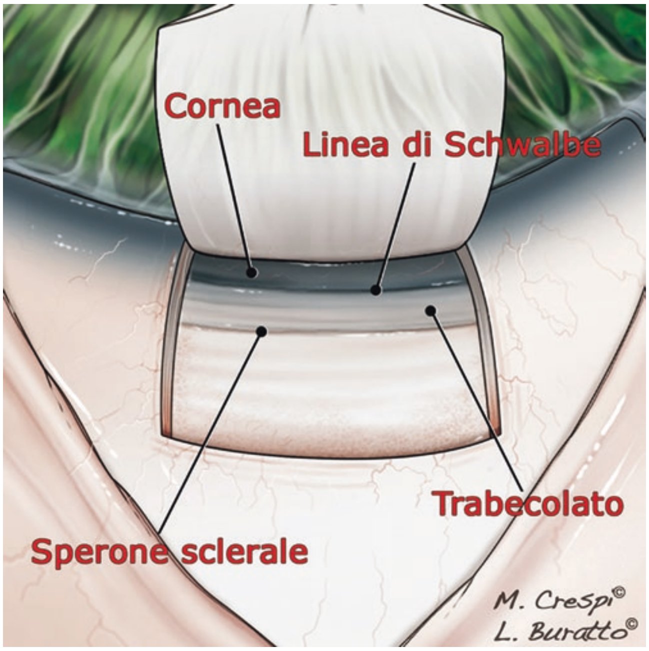

Fig. 1.3 Surgical anatomy of the limbus following sclera dissection. View of the main surgical landmarks during the dissection to create a scleral flap at a depth of 1/3 of the scleral thickness.

The posterior margin of the flap normally overlaps the anterior portion of the sclero-corneal trabecular meshwork. Schematically, we can identify the following structures, from anterior to posterior: the anterior margin of the limbus, consisting of the Schwalbe's line, the trabecular meshwork and the posterior margin consisting of the scleral spur: consequently, the surgical limbus includes the Schwalbe's line in the anterior portion, the trabecular meshwork in the middle and posteriorly, the scleral spur. When glaucoma surgery is performed, the surgeon must always be aware of these surgical landmarks

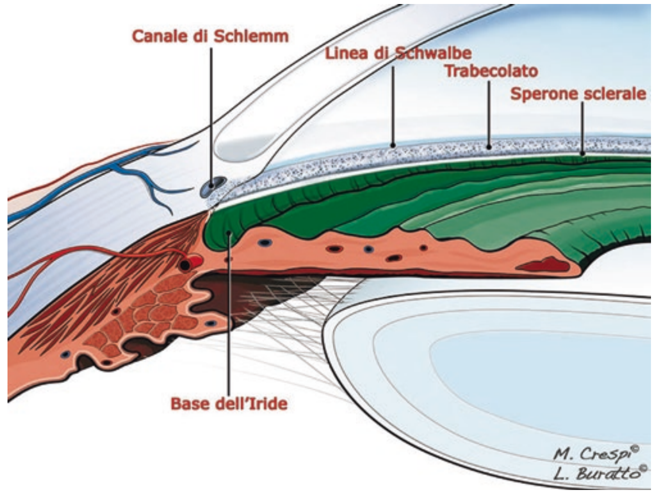

Fig. 1.4 Anatomy of camerular angle.

Iris root is another important anatomical landmark: in normal eyes, it is located 1.5–2 mm behind the limbus. However, in smaller eyes (hyperopic eyes), it will be found more anteriorly proportionally to the smaller dimension of the eye.

The ciliary body is located behind the insertion point of the iris root and below the scleral spur. Accidental incision of the ciliary body is an extremely serious surgical error. The ciliary body is a ring with an almost triangular section; it lies on the internal surface of the sclera and it extends from the scleral spur to the ora serrata. The ciliary ring projection on the scleral wall extends posteriorly for 7 mm from limbus in the temporal side and for 6 mm in the nasal sector.

When glaucoma surgery is performed, the surgeon must be aware of iris-corneal width and iris root insertion point. Infact, during this type of surgery, it is important to distinguish between an open and a closed irido-corneal angle.

1. When the angle is open:
   - if the incision is performed through the anterior edge of the limbus, the access to the anterior chamber (AC) will be anterior to the Schwalbe's line
   - if a middle-limbar incision is performed, the AC is accessed in correspondence to the Schwalbe's line
   - when a posterior incision is performed, it will lie above the scleral spur.
2. When the angle is closed:
   - a middle-limbar incision is considered as a surgical error as it penetrates the AC through the angle or even through the ciliary body, with potentially serious consequences. Consequently, a more anterior or anteriorly angled incision is recommended

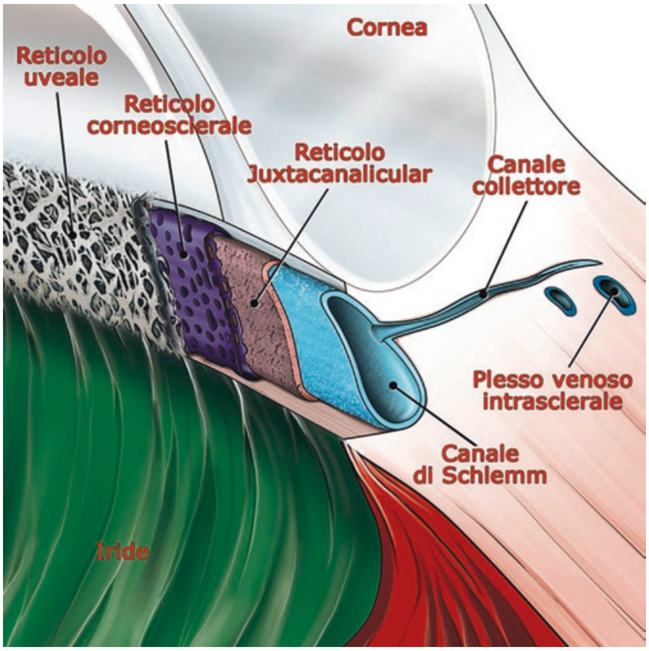

Fig. 1.5 Schlemm canal.
The Schlemm's canal is an important structure to know in order to perform some glaucoma surgeries, such as canaloplasty and the ab externo trabeculotomy. This is a circular canal creating a complete ring that extends for the entire circumference of the limbus. The Schlemm's canal has a diameter that varies between 190 and 370 μm; it is delimited laterally by the scleral spur and posteriorly by the filtering portion of the trabecular meshwork (refer also to Fig. 1.4). Its projection on the external surface of the eyeball lies immediately behind the posterior limit of the limbus. The Schlemm's canal is connected by an intrascleral venous plexus to an episcleral venous plexus: both of these venous plexus collect the Schlemm's collector channels and are important structures for the aqueous humor outflow. Regarding the gonioscopic aspects, the most important reference points are the scleral spur and, when visible, the Schwalbe's line

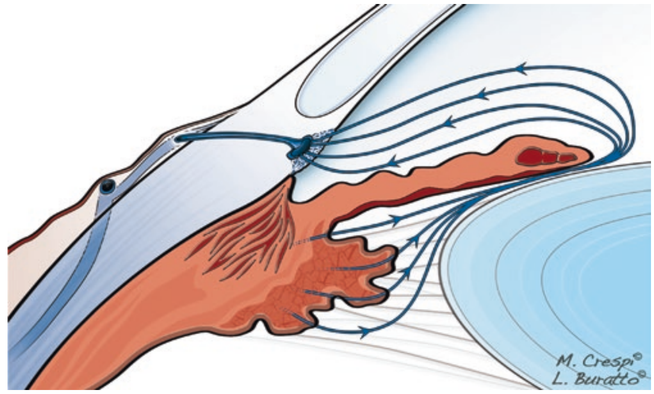

Fig. 1.6 Outflow pathways of aqueous.
The glaucoma surgeon must also be familiar with trabecular meshwork physiology to better comprehend the rationale behind the most recent anti-glaucomatous surgical techniques, such as the new mini-invasive anti-glaucomatous surgical techniques (MIGS). The trabecular meshwork and the internal wall of the Schlemm's canal are the main outflow routes for the aqueous humor. The aqueous humor exits the eyeball through the dense sieve of the trabecular meshwork. The aqueous humor reaches the adjacent Schlemm's canal, that drains directly into the aqueous veins. The trabecular network contains three different layers. The layer of tissue closer to the AC is the uveal trabecular meshwork. This consists of a network of connective tissue extensions that originates from the iris and the ciliary body. This layer does not provide high resistance to the outflow of the aqueous humor because the intercellular spaces are large. The next layer is the sclero-corneal trabecular meshwork, characterized by lamellas covered with epithelial-like cells that lies on a basal membrane. The lamellas consist of glycoprotein, collagen, hyaluronic acid and elastic fibers. The third layer is the juxtacanalicular trabecular meshwork, that is in direct contact with the internal wall endothelial cells of the Schlemm's canal. It consists of cells contained in a dense extracellular matrix. This layer provides the greatest amount of resistance to the outflow of aqueous humor because the intercellular spaces are very narrow. Finally, the aqueous humor crosses the endothelial cell layer of the Schlemm's canal, that is the final barrier that the aqueous humor has to overcome before it exits the eye

2 Anesthesia

Luigi Caretti and Lucio Buratto

Introduction

The anesthesia used in a surgical procedure for glaucoma depends primarily on the surgeon's personal preferences. However, the complexity of the surgical procedure, the presence of other systemic clinical conditions and patient collaboration also play important roles.

A glaucoma surgical procedure, alone or in combination with phacoemulsification, can be performed under general or topical anesthesia, but more frequently loco-regional (retrobulbar, peribulbar, sub-Tenon) anesthesia is preferred.

Across the world, most surgeons perform these procedures under local anesthesia, with cardio-vascular monitoring and a venous line open available. It is advisable to have an anesthetist on call to manage any possible adverse events, despite these being extremely rare.

Sometimes it may be useful to associate low grade sedation to the local anesthesia. Using local (or topical) anesthesia has several advantages over general anesthesia:

- Lower morbidity and mortality associated with general anesthesia
- Lower incidence of nausea and post-operative vomiting
- Better cardio-pulmonary stability
- Rapid return to walking
- prolonged post-operative analgesia
- lower costs.

The most common agents used for local anesthesia are mepivacaine (duration of action: 45–90 min), lidocaine (duration of action: 1.5–2.5 h), bupivacaine (duration of action: 2–4 h) and ropivacaine (duration of action: 2–6 h). The longer duration of action of ropivacaine gives the patient a couple of extra hours of post-operative analgesia.

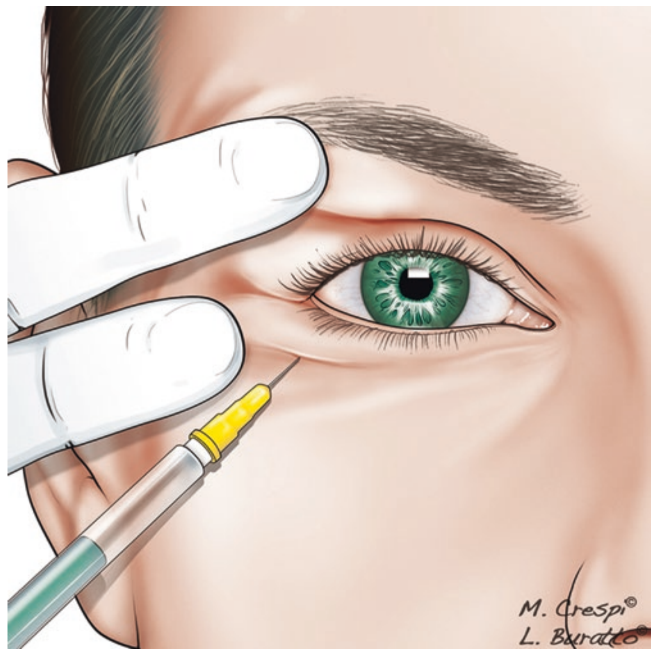

Fig. 2.1 Retrobulbar anesthesia used in glaucoma surgery

The retrobulbar block is the elective choice for most surgeons, as a good degree of akinesia and analgesia can be achieved with a limited amount of anesthetic agent. Compared to peribulbar anesthesia, it reduces the possible increase of intraorbital pressure (Fig. 2.1).

Retrobulbar Anesthesia in Glaucoma Surgery

Generally-speaking, a blunt 25G needle is used (Atkinson retrobulbar needle Eagle Labs, Rancho Cucamonga, California). The technique can include also injecting 2 cm^3 of the

L. Caretti (✉)
Santa Maria della Misericordia Hospital, Rovigo, Italy
e-mail: oculistica.ro@azisanrovigo.it

L. Buratto
Centro Ambrosiano Oftalmico, Milan, Italy
e-mail: iol.lasik@buratto.com

L. Caretti, L. Buratto (eds.), *Glaucoma Surgery*, http://doi.org/10.1007/978-3-319-64855-2_2

anesthetic agent into the eye's internal canthus. It is advisable to associate a small quantity of hyaluronidase (5 U\mL, that is 0.5–1 mL in the 10 mL syringe) to facilitate the diffusion of the anesthetic agent. Akinesia of the orbicularis muscle is achieved by slowing injecting 1.5 mL of anesthetic in front of the orbital septum.

In the event the surgeon opts for peribulbar anesthesia, four periconic injections should be performed in the four quadrants to allow a better distribution of the anesthetic agent.

Sub-Tenon anesthesia has the advantage of not increasing the intraorbital pressure, due to the small quantity of anesthetic agent injected (1.5 mL) and the disadvantage of a greater haemorrhage risk. Several different quadrants have been proposed for the injection: supero-temporal, internal canthus and infero-nasal.

In all cases of injected anesthesia, the block can be achieved by using 2% carbocaine (or 2% lidocaine) possibly in association with 0.50% Marcaine (1:1) if the procedure is expected to last longer than normal.

Digital eye massage consents better diffusion of the anesthetic solution and reduces the intraocular pressure (IOP); this is an important phase in the preparation of the patient for surgery. However, many surgeons do not apply this technique because they believe it induces an additional transitory IOP increase—dangerous for patients affected by glaucoma; pressure values are maintained at between 30 and 40 mm Hg for approximately 20 min.

If total eyelid akinesia is required, a facial nerve block can be associated (Van Lint).

Some authors use topical anesthesia—4% xylocaine and 0.5% tetracaine HCl; in this case, in addition to topical anesthesia, the surgeon may also opt for an intracamerular injection of preservative-free 1% xylocaine. Good exposure of the operating field can be achieved by asking the patient to look downwards.

Generally-speaking, surgeons will opt for a form of anesthesia that will produce total akinesia, considering the fine surgical maneuvers required as the scleral flap dissection.

General anesthetic is usually reserved for patients not suitable for local anesthetic—children, adults who suffer from claustrophobia, patients who are extremely anxious or affected by an altered mental state, those with a history of poor collaboration during previous surgeries under local anesthesia, patients affected by nystagmus, tremors or those patients who are unable to lie in a supine position for any length of time. Some surgeons prefer to use general anesthesia for great personal peace of mind during surgery; others consider local anesthesia to be associated with greater risk in some patients (those with serious blood-clotting disorders, or with very long eye bulbs, for example in cases of severe myopia or congenital glaucoma).

The above comments apply to all of the surgeries described in this book.

Bibliography

1. Hustead RH, Hamilton RC, Loken RG. Periocular local anesthesia: medial orbitala s an alternative to superior nasal injection. J Cataract Refract Surg. 1994;20:197–201.
2. Greenbaum S. Ocular anesthesia. Philadelphia: WB Saunders; 1997.
3. Vicari D, McLennan S, Sun XY. Tropical plus subconjunctival anesthesia for phacotrabeculectomy: one year follow-up. J Cataract Refract Surg. 1998;24:1247–51.
4. Anderson CJ. Circumferential perilimbal anesthesia for combined cataract glaucoma surgery. Ophthalmic Surg Lasers. 1999;30: 205–7.

3 Penetrating Surgery and Its Surgical Variants

Luigi Caretti and Lucio Buratto

Introduction

In general, surgery and/or parasurgical laser treatment for glaucoma are indicated in case of poor tonometric control, or in the event of poor patient compliance to treatment. Several surgical options are available; they have different degrees of efficacy and also different complication rates. The decision regarding the treatment pathway is taken on a case by case basis, and this makes a standard treatment protocol difficult to define.

Of the various surgical options, trabeculectomy is still the gold standard in antiglaucoma surgery, particularly when associated with the use of antimetabolites.

Traditionally, trabeculectomy is indicated in the following cases:

- Uncontrolled open- or closed-angle glaucoma
- Open- or closed-angle glaucoma controlled with more than two drugs (to achieve very low IOP)
- Post-traumatic glaucoma
- Unsuccessful glaucoma surgery.

Trabeculectomy reduces the intraocular pressure (IOP) by allowing the aqueous humor outflow from the anterior chamber (AC) into the subconjunctival space or, more precisely, below the Tenon capsule; this filtration occurs through an opening in the scleral wall at the altered trabecular meshwork.

L. Caretti (✉)
Santa Maria della Misericordia Hospital, Rovigo, Italy
e-mail: oculistica.ro@azisanrovigo.it

L. Buratto
Centro Ambrosiano Oftalmico, Milan, Italy
e-mail: iol.lasik@buratto.com

The extraocular space below the conjunctiva in which the discharged aqueous humor accumulates is called a bleb and this is subsequently drained by the blood vessels.

The trabeculectomy procedure guarantees excellent tonometric and visual results in the vast majority of eyes operated. However, providing the numbers and the precise percentages continues to be a laborious task, due to difficulties associated with comparing the various published works. These studies are often different in terms of the method used (retrospective or prospective, randomized or not, etc.), and due to the numerous variants of the surgical technique.

In recent times, many surgeons associate anti-metabolites with the trabeculectomy procedure: the antimetabolite would appear to improve the efficacy of the procedure, even though some authors believe there is no solid scientific evidence to support clear superiority of mitomycin-C (MM-C) compared with the standard trabeculectomy procedure.

Surgical Technique

As previously mentioned, the trabeculectomy procedure reduces the IOP by allowing the aqueous humor drain into the sub-conjunctival space, or more precisely, to below the Tenon capsule; this filtration occurs through an opening in the scleral wall at the level of the trabecular meshwork and is inevitably influenced by post-operative scarring involving the conjunctiva and the Tenon capsule.

We will now describe probably the most popular trabeculectomy technique. However, a variety of modifications may be introduced during the various phases of the procedure, such as: type of conjunctival limbus, type of scleral access, use of antimetabolites and the method used to remove the scleral-corneal block.

L. Caretti, L. Buratto (eds.), *Glaucoma Surgery*, http://doi.org/10.1007/978-3-319-64855-2_3

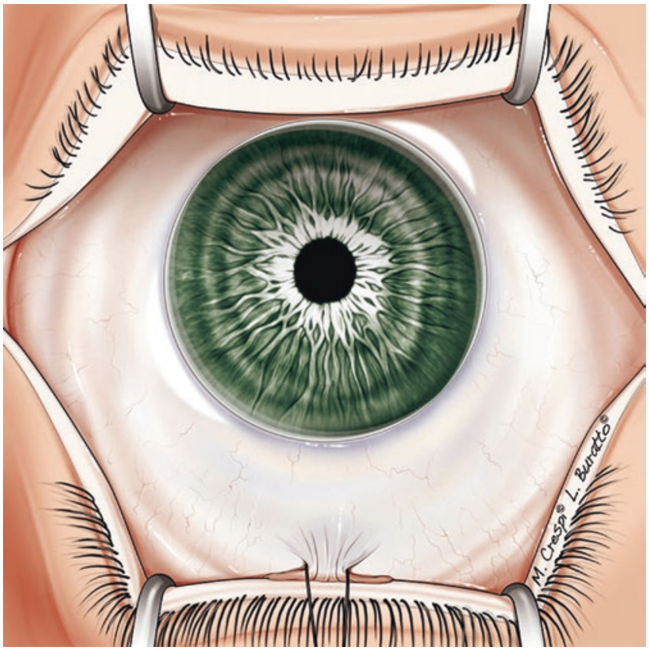

Fig. 3.1 Exposure of the operating field. The first step of the procedure is the correct exposure of the operating field; this will provide the surgeon with easy access to the delicate ocular structures he will be handling. Placement of a traction suture, normally in 4.0 silk, in the superior rectus muscle has proven to be useful in the event the surgery is performed under loco-regional or general anesthesia: it will be tight during the scleral surgical phases and released during the phases on the cornea or in the AC. Dedicated forceps (Graefe or Verzella forceps) are generally used to catch the muscle. Once the suture has been passed through the tissue, the silk suture is anchored with a Dieffenbach clamp or small Pean forceps

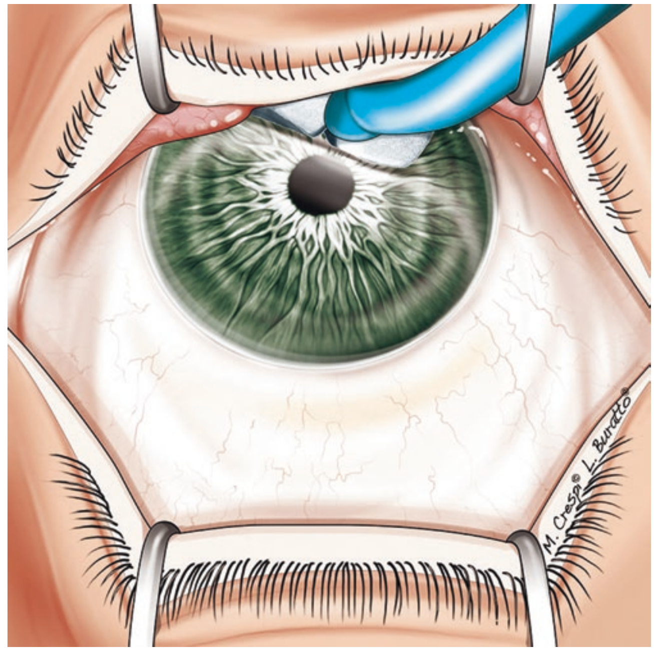

Fig. 3.2 Exposure of the operating field in the scleral phase. As an alternative to the traction suture, to achieve good exposure of the operating field in the scleral phase, the surgeon can wedge a suitably shaped merocel sponge into the blepharostat. With this maneuver, the surgeon can rotate the bulb (inferoversion) and this will provide him with easy access to the superior sector of the sclera. Once the scleral phase of the operation has terminated, the sponge is removed and the eye bulb returns to its original position to allow the subsequent phases of the surgery on the cornea or in the AC to be performed

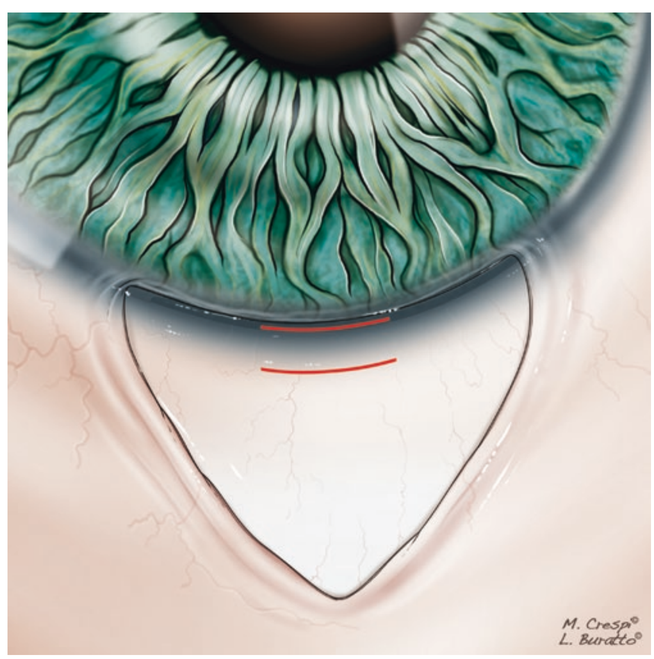

Fig. 3.3 Preparation of scleral bed. In the first phase of the operation, the surgeon creates a conjunctival-capsular flap at 12 o'clock, with a base at the limbus or the fornix; the width of the incision must be approximately 6–7 mm; in case of limbus based flap the incision is created about 8–10 mm from the limbus. The choice of the flap (with the base at the fornix or the limbus) depends substantially on the surgeon's preference and the requirements of the individual case. The fornix based hinge is the more popular. Following the preparation of the conjunctival-capsular flap, the scleral bed and the surgical limbus are exposed (*red line* in Fig. 3.3; refer also to chapter "Anatomy", Fig. 1.3). Diathermy is used to stop any bleeding from the scleral surface; this procedure must be relatively conservative as it must not affect the scleral tissue. Prior to the creation of the conjunctival-capsular flap, the surgeon must control the position of the venous collectors (perforating) to avoid these being cut: it is extremely important to avoid detaching the conjunctiva at a point where it is will not be possible to perform the subsequent phases of the procedure due to perforating vessels presence. The surgeon should delicately rub a blunt instrument (for example the closed arms of Westcott scissors) over the surface to create a transitory ischemia of the conjunctiva; this will provide a clear view where the venous collectors are positioned. In this way, the surgeon can select the most appropriate point to start the conjunctiva-capsular detachment

Fig. 3.4 Creation of scleral flap. Once a suitable area has been identified, preferably lying between two venous collectors, the surgeon creates the scleral flap. This dissection should be extended for 1 mm in clear cornea (indicated by the *broken red lines*). The flap can be created in a range of different shapes and dimensions. Normally, it is trapezoidal (but it can be rectangular, square, triangular or circular); the dimensions can vary between 5 × 5 and 4 × 3 mm. The thickness is approximately 200–250 μm, that is approximately one-third of the scleral depth. The optimal depth of the incisions is indicated in the drawing with oblique red lines. Common mono-use blades or better a pre-calibrated diamond lancet can be used